the rise of blood pressure respiration occurred, even although a much higher intracranial tension was maintained than had been sufficient to arrest it when the blood pressure was lower.

II. By the direct application of pressure in the upper part of the 4th ventricle a slowing of the heart with a rise of blood pressure was caused, whilst rapid respiration continued, so rapid as even to be nearly three times the rate of the heart in some cases. Pressure below the calamus scriptorius arrested the respiration without directly influencing the heart, whilst in the lower part of the 4th ventricle respiration was impeded or arrested along with a fall in blood pressure, and some slowing of the heart, followed by arrest, after the respiration had ceased.

Numerous observations are recorded which are, in many cases, combinations of the foregoing, and therefore not suitable for condensation in this abstract.

Tracings are furnished illustrating each point advanced.

X. "On the British Earthquakes of 1889." By CHARLES DAVISON, M.A., Mathematical Master at King Edward's High School, Birmingham. Communicated by Professor T. G. BONNEY, D.Sc., F.R.S. Received June 16, 1890.

(Abstract.)

The nature of the evidence on which the accounts are founded is stated, and the method of study described. If the disturbed area be of small dimensions, and if its boundary be approximately circular or slightly elliptical in form, it is assumed that the centre of the area coincides very closely with the epicentrum of the earthquake. During the year 1889 there were at least five earthquakes whose epicentra were situated within the area of the British Islands.

1. *Edinburgh Earthquakes*, *January* 18.—(*a*.) First shock about 4 h. 10 m. Intensity (according to the Rossi-Forel scale, of which a translation is given) about V. Very little is known about this shock.

(*b*.) Second shock, 6 h. 53 m. Intensity VI. The disturbed area is slightly elliptical in form, being 30 miles long from north to south and $26\frac{1}{2}$ miles broad from east to west; area about 620 square miles. In most places the shock consisted of a single vibration. The characteristic earthquake-sounds were heard in many places, and these places are confined to an area which is neither coextensive nor concentric with the disturbed area. The epicentrum is at a point about 3 miles W. 42° S. of Balerno, and the centre of the sound-area about $2\frac{1}{2}$ miles to the south or south-east of this point. The earthquake was probably

connected with the first of the N.W. and S.E. faults of the Pentlands on the north-west side of the axis; a fault which passes close by the centre of the sound-area, and has a downthrow to the north-west. The inclination of this fault is unknown, but is probably about 75° to the horizon; the depth of the seismic force may therefore be about $8\frac{1}{2}$ miles. It is shown that the earthquake was probably caused by the impulsive friction produced by a slip of the fault referred to; that this slip took place near the middle of the length of the fault; that the slip increased the throw of the fault; that the slip-area was very short, possibly less than a mile in horizontal length, but that it extended from a depth of several miles to within a short distance of the surface.

2. *Lancashire Earthquake, February* 10.—22 h. 36 m. Intensity VI. The disturbed area is nearly circular in form, about 55 miles in diameter, and 2480 square miles in area. The nature of the shock varied with the position of the place of observation. In, or nearly in, a line with the Irwell fault the number of vibrations was generally greater than in places more remote. As in the Edinburgh earthquake, the usual sounds were heard in many places which are confined to a nearly circular area, which is neither coextensive nor concentric with the disturbed area. The duration of the sound was generally greater at places in, or nearly in, a line with the Irwell fault than at places more remote. The epicentrum, which is probably coincident with the common centre of the disturbed area and of the isoseismal line of intensity V, is at a point 2 miles N.N.E. of Bolton, and the centre of the sound-area is about $3\frac{1}{4}$ miles S.S.E. of the epicentrum. The earthquake was probably caused by a slip of the great Irwell fault, which passes close by the centre of the sound-area, having a downthrow to the north-east. If so, the slip must have increased the throw of the fault. The horizontal length of the slip-area was possibly not much more than a mile. The seismic focus is perhaps at a depth of about $3\frac{3}{4}$ miles, but the slip seems to have extended to within a short distance of the surface.

The excentricity of the sound-area in these two cases throws light on the origin of the sound-vibrations. Seismographic records show that near the beginning of an earthquake the period increases with the amplitude, and it is suggested that the sound-vibrations are the very minute vibrations of short period which proceed from the upper and lateral margins of the slip-area. It is pointed out that this theory explains all the known characteristics of earthquake-sounds.

3. *Ben Nevis Earthquake, May* 22.—13 h. 58 m. Intensity about IV. This shock may have been connected with the great fault which crosses Scotland from Inverness in a south-west direction.

4. *Kintyre Earthquake, July* 15.—About 18 h. Intensity V. The disturbed area is roughly elliptical in form, the longer axis being in

a direction about N. 30° E. to S. 30° W.; it is about 25 miles long and 18 miles broad, and about 350 square miles in area. The sound-area appears to be coextensive with the disturbed area, but the observations are too few in number to prove this. The epicentrum is about $3\frac{1}{2}$ miles south-east of Clachan. Dr. Lapworth, in a note to the author, describes briefly the geological structure of the disturbed area, and remarks that its longer axis coincides in direction with the theoretical position of the southern zone of contrary movement in that district.

5. *East Cornwall Earthquake, October* 7.—About 13 h. 45 m. Intensity IV. The disturbed area is elliptical in form, 25 miles long and 20 miles broad, the longer axis running east and west, and about 400 square miles in area. The nature of the shock varied somewhat throughout the disturbed area, but its intensity was very nearly constant. Near the centre of the area the earthquake-sounds were the most prominent feature, but towards the boundary these died out. The sound-area may, however, have been coextensive with the disturbed area, and it is probable that the sound-focus is nearer the surface than the seismic focus. The epicentrum is at a point about $2\frac{3}{4}$ miles south-west of Altarnon, which is not far from the centre of the great granite boss of eastern Cornwall. The longer axis of the disturbed area is also parallel to the axis of folding of the district.

Doubtful Earthquakes.—Two shocks, supposed to be those of earthquakes, are briefly described, but the evidence is insufficient to prove their seismic origin:—(1) Little Rhondda Valley (S. Wales), June 22, about 22 h. 30 m.; (2) Lyme Regis, July 5, between 23 h. and 23 h. 15 m. The former of these may possibly have been caused by subsidences of the rock over worked-out portions of the coal mines.

In conclusion, the differences between British and Swiss earthquakes are pointed out. The former are rare, and their disturbed areas more or less circular, indicating short fault-slips; the latter are frequent, and their disturbed areas elongated, their axes being parallel to those of the neighbouring mountain ranges, and the fault-slips correspondingly long. They are witnesses respectively of comparatively late and early stages in the process of mountain evolution.